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ABSTRACT

In the speech the main point is made that the human ecosystem of the world is subject to scientific inquiry and as a consequence a new way is needed to view the planet earth. Three sets of facts have now been stablished concerning the earth and its inhabitants: 1) the earth and its life forms constitute a system; 2) the many sub-systems of life --molecules, cells, organisms, species, and societies-- are a part of a highly complex and interdependent ecosystem; 3) human society is an integral part of that ecosystem. The ecosystem, which behaves "intelligently", grows, adjusts, recuperates, etc., in order to remain viable. The question thus to be answered is, how can human society contribute rather than detract from that viability? The answer is given in the advice that education can play a very important role in reorienting man's thinking so that he sees himself as part of the ecosystem rather than being against it. Such a reorientation is felt to be not only necessary for the preservation of the ecosystem, hence human life, but it opens new vistas for the development of mankind. (CWB)

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An Ecosystem Approach to a Livable Environment for Man*

The point I shall try to make is that the human ecosystem of the world, despite its seemingly overwhelming complexity, is subject to scientific inquiry and comprehension through an approach in which human-society-plus-its-total-environment is viewed as a unified system. This approach provides a basis for a reorientation of knowledge through which education can be made more meaningful in the context of the contemporary world. To accomplish this objective I intend first to provide an overview of the planet Earth with broad brush strokes, then to develop some concepts about integrated systems dynamics and an appreciation for the complexity of the structure and behavior of the human ecosystem as a whole, and finally to direct attention toward phenomena of the human ecosystem. A total ecosystem approach, including the man system as a component of the whole, is, I think, the only logical approach to a livable environment for man, or better still, a living human ecosystem.

The earth has been seen and photographed from outer space, making it incomparably more believable now than ever before that the planet Earth is indeed a unified and unique system, at least in that part of the universe that we can adequately perceive. It is

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unique in that it is a living system. I mean not merely that the earth has life, in contrast to other planets, but that it is an integrated living system reflecting the collective behavior of the component parts. When viewed from outer space one senses that the earth's strong colors and swirling masses of white clouds reveal megaprocesses at work, integrating various parts of a coherent system. One way of viewing the earth is in terms of its great envelopes: the lithosphere, pertaining to the nonliving solid earth; the atmosphere, describing the nonliving gaseous envelope; the hydrosphere, designating the nonliving aquatic aspect; and the biosphere, including all of the living organisms taken as a whole, exclusive of the nonliving environment. The envelope of the mind, or "noosphere," to encompass the collective human mind of the earth, or the "thinking layer," is now being accepted as another of the earth's spheres. Collectively these five spheres can be thought of as the earth's ecosphere. Taking the earth as a single unified system the processes through which the spheres are integrated may be considered the internal physiology of the system, to emphasize that one is dealing with one system characterized by powerful integrative forces and processes. The hydrologic cycle, for example, carries some of the basic elements of living systems -- carbon, hydrogen, oxygen, nitrogen and sulphur -- from the hydrosphere by evaporation into the atmosphere and by condensation coupled with photosynthesis and absorption back to the hydrosphere by the way of the biosphere and/or lithosphere.

It is well to remember that: (1) during the first billion or so years of the earth's 4 1/2 billion year history there was no biosphere, (2) the diversity of the biosphere has embraced perhaps as many as one billion different species of living organisms over a period of somewhat more than 3 billion years, (3) over 99% of the species have become extinct, and (4) the noosphere is a recent innovation dating back a mere 2 1/2 million years or so.

The ecosphere provides a useful introduction to the planet Earth in terms of its living and nonliving components, and serves as a basis for understanding ecospheric processes. It also helps to introduce the concept of the human mind as a new sphere within the total context of the system earth. On the other hand, this approach is somewhat inadequate for comprehension of the earth's true nature as a dynamic integrated system.

Conceptually, the ecosphere can be considered equivalent to the total world ecosystem. An ecosystem in a geographical area is commonly perceived as the living communities of organisms together with the total nonliving environment, taken as an integrated whole in nature. Collectively the regional ecosystems constitute the world ecosystem. The human species now dominates the world ecosystem to such an extent that one can appropriately speak of a world human ecosystem, or the human-society-plus-total-environment level of biological integration. Starting with this highest and most complex level of biological organization, one can proceed conceptually downward through an indefinite number of hierarchically organized systems, including human ecosystems;

nonhuman ecosystems; biocommunities; communities of plants, animals, or microorganisms; intraspecific populations; individual living organisms; organs and tissue systems; cells; cellular organelles; molecules; and atoms. Each level of organization is characterized by unique, predictive integral configurations, or characteristics, that enable one to identify, study, and manipulate or manage the system. Starting from what seem to be the most irreducible units of nature, the subatomic particles, one can begin to move back up through the organized systems while carrying along a network theory of integrated dynamic systems. I am borrowing here from an elucidation of system concepts by Paul A. White, of Rockefeller University, in a book to be published in the spring of 1971. In network theory units form the nodes at the intersections of a three-dimensional web. A unit may be defined as a fragment of the universe which in our experience exhibits integral configurations by which it can be recurrently identified, although functionally the boundaries of a unit blend with its environment. The interplay, or interactions, between the units form the strands of the weblike network, the whole of which is enmeshed in an environmental matrix. Through these interdependent interactions within the environmental context field continuous and integral guidances are established. The collective state of the system is such that the units appear to cooperate "intelligently" in producing an effect that is more than a mere summation of the interactions. In an elastic network the strands seem to "know" exactly how to adjust, on release from being stretched, to return to an original state of homeostatic equilibrium. The integral configurations of the whole are unique for the system, different from other systems, and not predictable from knowledge

of the units in isolation from the context of the total system. Despite considerable indeterminacy of the interactions of the component parts, integral configurations of structure and behavior emerge and are preserved, and the system tends to restore itself after nondestructive disturbances. Herein lies the essence of systems and the rationale for believing that the human ecosystem is capable of being understood, and managed intelligently, despite its enormous variability and complexity. Systems are also characterized by optimum combinations of fixed chain reactions and free systems dynamics, providing for both efficiency in the functioning of the system and opportunity to react adaptively to a changing environment. Food chains or stereotypic chains of behavioral patterns in which one interaction triggers another, as in a mating sequence, are examples of fixed linear reactions. At the same time the free systems dynamics keeps open the options for evolutionary adaptation. In the higher living systems -- including populations, communities, and ecosystems -- individual organisms can be viewed as symbolically comparable to subatomic particles, and the concept of field-particle complementarity in physics can be applied as a field-organism complementarity in higher living systems from the population upward.

The number of component units, and the potential interplay among the different kinds of units, provides some measure of the increased complexity as one moves upward from atoms to ecosystems. About 50 subatomic particles are involved in the formation of some 100 chemical elements, each of which is an organized system determined by the pattern of relations among the component particles. Molecular systems are based on about 100

chemical elements, and living cellular systems are based on a few thousand naturally occurring simple molecules. Presently there are some 5 to 10 million living species of organisms that provide the component units of the world ecosystems. These living species represent less than 1% of all the species estimated to have evolved since life began on the planet, which provides an appreciation for the evolutionary development of both species components and whole ecosystems. Ecosystems evolve as well as individual species. Thus the complexity of ecosystems is infinitely greater than that of any of its subsystems; and when one considers that the evolution of the human mind over the past 2 1/2 million years has further increased the complexity of an already enormously complex world ecosystem, one begins to realize that the earth's living system is not only more complex than one thinks it is but more complex than one can think. It is this very complexity that provides the resilience of ecosystems to recover from nondestructive disturbances, and the complexity itself must be preserved in man's endeavor to develop a livable environment.

In the network model of an ecosystem individual species constitute the nodal points, and the interactions between species determine the field continuua through which the integral configurations of structure and behavior of the ecosystem are determined. At a given time and place in nature the species is represented by a population of individuals, the individuals interacting with one another and with individuals of different species. Through their collective behavior individuals of the same species form intraspecific populations, uniquely identified by integral configurations expressed in such attributes as natality, mortality, intrinsic rates of

increase, sex and age structure, social organization, and social behavior. Populations of different species interact to form higher-order community systems with integral configurations perceived, for example, in the physiognomy of vegetation or sedentary marine animal communities, in predator-prey complexes, and in the suppressing effect of one population of grazing animals on another where environmental resources are limited. Patterns of communities-and-their-total-environment, or ecosystems, form a still higher level of biological integration, with systems structure and behavior different from that of systems lower in the hierarchy, as, for example, in the maintenance of systems integrity through the capture of energy from the sun in the process of photosynthesis and the subsequent flow of energy through consumer and decomposer organisms, or in biogeochemical cycles through which the chemical elements of living organisms are recycled, or in the niche structure of an ecosystem. There are no sharp boundaries for an operational ecosystem, and the selection of ecosystem units is in part a matter of convenience in research and management. The major ecosystems in geographical regions of the earth, such as deserts, grasslands, forests, tiga, tundra, and aquatic systems such as lakes, streams, estuaries, and the open ocean, involve interactions among many ecosystems as subsystems of the larger whole.

As an illustration of the numbers of interacting unit organisms, and the pattern of local ecosystems emerging from their collective state, consider Oxford University's estate at Wytham Woods, where Charles S. Elton studied the animal communities intensively for more than a quarter of a century.

Here a rich pattern of open fields, limestone outcroppings, woodland, springs, and marshes is set in riverine surroundings. The complexity of this pattern of ecosystems within an area of about two square miles can be appreciated from the diversity of animal life, which includes an estimated 5,000 species, about 3,800 of which have been identified. To the animals one must add numerous species of plants and microorganisms that are also essential components of the ecosystems at Wytham Woods. Each species is represented by populations varying from a few individuals, for some of the rarer plants and larger mammals, to billions for some of the microbes. Thus on an individual basis the number of interacting component units of living organisms in the system's network is astronomical, and the interplay among the organisms in their environmental context staggers the imagination. The model of a weblike system with units that interrelate in such a manner that their collective state produces emergent properties seems to be the best approach for understanding the immense complexity of ecosystems and their subsystems. Starting with individual organisms, one deals conceptually with systems within systems both upward and downward in a natural hierarchy of organized systems, all levels of which are ultimately pertinent to the the whole ecosystem.

The influence of man over centuries of time is reflected in the ecosystems at Wytham Woods, and the system man is every much an integral part of the ecosystem as any other component. One tends to separate man from the ecosystem because of his conscious mind through which he transcends many, but not all, of the biological constraints of all other living

organisms — restraints that have been conducive to the evolution of steady-state nonhuman ecosystems. As human consciousness evolved man saw himself as the center of the universe, and he has only recently begun to view himself and his societies in relationship to the total world ecosystem as a single unified system.

The social system of man can be separated conceptually from the ecosystem and considered from the viewpoint of integrated systems dynamics, without sacrificing the humanistic aspects that make the system so unique in comparison with populations of all other organisms. Despite the indeterminacy of individual human behavior, systems patterns do emerge for humanity as a whole, as expressed in the rich patterns of culture in various geographical regions of the earth, or in the common emotions all of us share with our fellow man. The psychology of individuals and of social groups lend themselves to scientific inquiry, although it is recognized that the complexity of the system man exceeds by several orders of magnitude that of any other natural system on earth.

If one accepts the viewpoint that human societies and their total environments form the highest level of natural systems, then scientific inquiry, education, social and political processes, and economics can be oriented at this level of biological integration in man's effort to achieve an integral harmony through which the world's human ecosystem can be stabilized and preserved as a dynamic, homeostatic system that provides a livable environment for man. This approach may be vital to the preservation of the integrity of the total world ecosystem, that is, its capacity to support life, including human life, at this point in the

evolution of the living earth. As Evelyn Hutchinson has pointed out, (Scientific American, September, 1970)

the current biological revolution invoked by the development of the human mind, or noosphere, and the impact of technology on the world ecosystem is comparable only to that revolution in living systems that occurred some 2 billion years ago at the transition from anaerobic metabolic respiration to aerobic respiration in which oxygen now plays an important role in the release of energy at rates several magnitudes above that which was possible in fermentation processes, thus setting the stage for an enormous diversity of species and the evolution of complex ecosystems, ultimately culminating in human ecosystems. In the current problems of overpopulation, environmental pollution, endangered species and endangered ecosystems, and quality of life, one witnesses the new biological revolution of the world ecosystem under the influence of the noosphere.

Human ecosystem processes are readily apparent once one accepts the concept of a unified system, rather than approaching the world through man on the one hand and the environment on the other. The effect on the world ecosystem brought about by the omnipresence of DDT may be viewed as a process at the level of human-society-plus-total-environment, since the synthesis of the compound and its release into nature stem from the minds of men. The outcome is still unpredictable. DDT could interfere with photosynthesis in marine phytoplankton, lowering the productivity of the oceans and reducing the amount of atmospheric oxygen. Such potential effects of new chemicals added to the ecosystem by man need serious consideration. Some 500 thousand new chemicals have been added in recent years, the effects of most of them being unknown. The megamachines of

human societies, which Lewis Mumford traces from the earliest civilizations to the present time, when taken in the context of the environment as unified systems, represent phenomena of the total ecosystem. In the giant industrial corporations that apparently have achieved cybernetic control of their own systems by eliminating competitive markets, dehumanizing and depersonalizing the component human beings, and turning tool-using men into machine-serving men, one finds another type of human-ecosystem phenomenon -- one that has crept up on man in his endeavor through technology to free himself from the biological constraints of his environment. The biological revolution emerging from the evolution of the noosphere brings mankind to a crossroads, where hopefully he still has a choice between dehumanized, highly populated ecosystems with limited opportunity for full development of human potentialities, and human ecosystems in which humaness and high quality of life are maximized.

In terms of "The Human Condition 1970: What Must be Done," the theme of this conference, it would seem that a reorientation of education on the world human ecosystem as a level of systems organization, rather than focusing primarily on man, would open the gates for innovation in teaching and make subject matters more interesting and more relevant to the contemporary world. Such an approach can be as humanistic as man-oriented approach, if one accepts the noosphere as an integral part of the system and the viewpoint that evolution of the world ecosystem is now occurring rapidly in the "thinking layer" of the ecosphere. A key to doing something about the environmental situation and the human condition through the

field of education lies in one's willingness to accept a new viewpoint of man and nature, and to apply it through reorientation of subject matter, a process that involves considerable self-education for the teacher. Fortunately, useful information and concepts are now appearing in books, journals, and magazine articles.

I would like to conclude by pointing out that the educational process is vital to the preservation of the free systems dynamics of the human ecosystem, and that education is therefore basic to evolution toward a viable, homeostatically stable and interesting world ecosystem in which the rich potentialities of the human species can unfold. The revolt of youth against much of traditional education may be a sign that better education in recent years has provided new insights, as yet vaguely discerned, to an understanding of man's integral relatedness to the total world ecosystem; and hopefully the process will lead to better education purposely focused on the human ecosystem, with an increasing influence on evolution toward a livable environment. Obviously, a more thorough foundation of knowledge about the human ecosystem must be developed through research, particularly regarding those emergent phenomena that are unique at this level of organization, but enough is known already to begin new approaches in education by reorienting subject matters in an ecosystem context.

In summary, it seems logical, on the basis of a natural hierarchy of organized systems and concepts of systems behavior, to believe in a level of systems integration that may be called the human ecosystem, or

the human-society-plus-total-environment level of organization. The human mind must be accepted as part of the system, and not as a phenomenon that transcends nature. The consequences of integrating the human mind with the nonhuman ecosystems that evolved over 3 billion years of time are seen in new and different integral configurations not found at any of the lower levels of biological organizations; and, despite its enormous complexity, the system is capable of being understood in terms of attributes that are unique. The challenge mankind faces today in bringing the human ecosystem under homeostatic control as a viable and changing system, in which that which is human in man can evolve to its fullest potential, is more meaningful when viewed in the context of a biological revolution comparable only to that which occurred about 2 billion years ago in the evolution of aerobic respiration. Once man, individually and as a society, faces squarely the idea that he is dealing with a new and higher-order ecosystem, one in which man himself is an integral part, he will have greatly enhanced the opportunity for gaining the necessary new insights required for the evolution of a world ecosystem that provides a livable, interesting, productive, and challenging environment for man.

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